JC07 Rec'd PCT/PTO 30 NOV 2001

FORM PTO-1390 U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**	ATTORNEY'S DOCKET NUMBER: 99.1091 U.S. APPLN. NO. (If known, see 37 CFR 1.5) 09/980016

INTERNATIONAL APPLICATION NO.:	INTERNATIONAL FILING DATE:	PRIORITY DATE CLAIMED:
PCT/NL00/00359	25 MAY 2000	31 MAY 1999

TITLE OF INVENTION: METHOD FOR DATA PROCESSING

APPLICANT(S) FOR DO/EO/US: Rogier EIJKELHOF

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   - a. [X] is transmitted herewith (required only if not transmitted by the International Bureau).
   - b. [ ] has been transmitted by the International Bureau. (see attached copy of PCT/IB/308)
   - c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   - a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   - b. [ ] have been transmitted by the International Bureau.
   - c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   - d. [ ] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Item 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A **FIRST** preliminary amendment.
    [ ] A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information:

International Search Report
PCT/IPEA/409
Application Data Sheet

Abstract of the Disclosure on a Separate Sheet

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CALCULATIONS PTO USE ONLY

17. [X] The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):

Neither international preliminary examination fee (37 CFR1.482) nor international search fee (37 CFR1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO .... $ 1,040.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .... $ 890.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $ 740.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) .... $ 710.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) .... $ 100.00

ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$ 130.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total claims	10 - 20 =	0	X $18.00	$	
Independent claims	1 - 3 =	0	X $84.00	$	
MULTIPLE DEPENDENT CLAIMS(S) (if applicable)			+ $280.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 1,020.00	
Reduction of ½ , if applicant is entitled to Small Entity status under 37 CFR 1.27. +				$	
SUBTOTAL =				$ 1,020.00	
Processing fee of $130 for furnishing the English translation later than months from the earliest claimed priority date (37 CFR1.492(f)).				$	
TOTAL NATIONAL FEE =				$ 1,020.00	
Fee for recording the enclosed assignment (37 CFR1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$ 1,020.00	
				Amount to be refunded:	
				charged:	

a. [X] A check in the amount of $ **1,020.00** to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. **25-0120** in the amount of $ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required by 37 CFR 1.16 and 1.17, or credit any overpayment to Deposit Account No. **25-0120**. A duplicate copy of this sheet is enclosed.

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November 30, 2001

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PATENTS

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Rogier EIJKELHOF

Serial No. (unknown)

Filed herewith

METHOD FOR DATA PROCESSING

PRELIMINARY AMENDMENT

Commissioner for Patents

Washington, D.C. 20231

Sir:

Prior to the first Official Action, please substitute page 1 and pages 4-10 of the specification as originally filed, with page 1 and pages 4-10 as filed in the Article 34 amendment of August 20, 2001. The pages are marked "AMENDED SHEET" and are attached hereto.

Prior to the first Official Action and calculation of the filing fee, please substitute Claims 1-12 as originally filed, with Claims 1-10 as filed in the Article 34 amendment of August 20, 2001. The pages containing Claims 1-10 are marked "AMENDED SHEET" and are attached hereto. Following the insertion of Claims 1-10, please amend these claims as follows:

IN THE CLAIMS:

Amend claim 4 as follows:

--4. (Amended) Method according to claim 1 characterized in that the direction in which said adjustement is performed depends on the relative difference between said target value calculated by weighted interpolation (P_t) and said minimum and maximum value (I_{min}, I_{max}).--

Amend claim 5 as follows:

--5. (Amended) Method according to claim 1 characterized in that use is made of weighted interpolation on the basis of a non-linear density distribution which assigns a heavier weighting to source values located closer in the grid than to source values located further away, in particular a Gaussian distribution, at least an exponential density distribution.--

Amend claim 6 as follows:

--6. (Amended) Method according to claim 1 characterized in that a source value which lies in the grid closest to the target value to be determined, is taken as source of a region extending over a finite number of mutually adjacent source values and that the local maximum and the local minimum are determined in this region.--

Amend claim 10 as follows:

--10. (Amended) Method according to claim 1 characterized in that the final target value is a weighted average of the target value determined on the basis of interpolation and the local maximum and minimum, wherein a weighting factor is employed which depends on average local

dynamics of the source values located around the target value to be determined and the relative location of the target value determined on the basis of interpolation relative to the local maximum and minimum.--

REMARKS

The above changes in the specification and claims merely place this national phase application in the same condition as it was during Chapter II of the international phase, with the multiple dependencies being removed. Following entry of this amendment by substitution of the pages, only claims 1-10 remain pending in this application.

Rogier EIJKELHOF

Attached hereto is a marked-up version of the changes made to the claims by the current amendment. The attached page is captioned "VERSION WITH MARKINGS TO SHOW CHANGES MADE".

Respectfully submitted,

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November 30, 2001

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

The claims have been amended as follows:

4. (Amended) Method according to ~~any of the preceding claims~~claim 1 characterized in that the direction in which said adjustement is performed depends on the relative difference between said target value calculated by weighted interpolation (P_t) and said minimum and maximum value (I_{min}, I_{max}).

5. (Amended) Method according to ~~any of the preceding claims~~claim 1 characterized in that use is made of weighted interpolation on the basis of a non-linear density distribution which assigns a heavier weighting to source values located closer in the grid than to source values located further away, in particular a Gaussian distribution, at least an exponential density distribution.

6. (Amended) Method according to ~~any of the preceding claims~~claim 1 characterized in that a source value which lies in the grid closest to the target value to be determined, is taken as source of a region extending over a finite number of mutually adjacent source values and that the local maximum and the local minimum are determined in this region.

10. (Amended) Method according to ~~any of the preceding claims~~claim 1 characterized in that the final target value is a weighted average of the target value determined on the basis of interpolation and the local maximum and minimum,

wherein a weighting factor is employed which depends on average local dynamics of the source values located around the target value to be determined and the relative location of the target value determined on the basis of interpolation relative to the local maximum and minimum.

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Method for data processing

The present invention relates to a method for processing data in the form of a grid of discrete source values, wherein at least one target value within a region of source values is determined by means of interpolation in said region of source values.

Such a method can be used for data of diverse nature, and particularly to expand, compress or decompress computer data with a non-critical bit value, such as for instance sound and animation files. The starting point is always a one- or multi-dimensional grid of discrete source values among which concrete target values have to be predicted by means of interpolation. The source values herein comprise numerical values which, in the case of for instance an image, indicate the colour intensity of a basic colour present therein and, in the case of a sound file, represents the frequency, i.e. the pitch, or the intensity thereof. In the case of other types of data a different information component in the source data will similarly be taken as measure.

For digital images there exists a number of more or less standardized forms in which the data is stored. The so-called bitmap format is for instance a form wherein the data is stored in a series of discrete numerical values. This series can be converted comparatively simply into a two-dimensional matrix of source values which each indicate the colour intensity of pixels corresponding therewith. In a monochromatic image there thus results a single matrix, while in a colour image such a matrix can be constructed for each of the basic colours.

One of the simplest ways of enlarging such an image is to expand the discrete pixels. The result hereof is shown in figures 1 and 4, wherein the lower image T 1 is roughly a five-fold enlargement of the source image S. It can be seen clearly that such a method of enlargement detracts significantly from the resolution of the final image. Because each pixel of the source image S reappears in the result T1 as a rectangular image area of a uniform colour (intensity), a clear block structure is created which does not correspond with the original source image.

AMENDED SHEET

In the context of the present invention local dynamics in the source values are understood to mean the degree in which the source values in the relevant region differ from each other and also the steepness with which these differences are present. A further particular embodiment of the method according to the invention comprises in this respect an algorithm which assigns a numerical value hereto and is characterized for this purpose in that the dynamics are derived from a normalized difference between a source value and an average of all source values in the second region. For the average of all source values in the second region a weighted average is herein preferably taken which assigns a heavier weighting to source values located closer in the grid than to source values located further away and which particularly utilizes a non-linear density distribution for the purpose of determining the weighting factors and more particularly a Gaussian distribution, at least an exponential density distribution.

In order to determine the different factors which play a part in predicting the target value within the scope of the invention, the starting point is always a number of source values in a finite first and second region as frame of reference. Relatively far-removed source values can be ignored because they make no or hardly any contribution towards the precision with which the target value is calculated and can even detract from this precision in that there is alack of any relationship with the target value for predicting. The calculation time of the method moreover increases when more source values are taken as frame of reference. Conversely, only one or two reference values will in many cases be too few to enable prediction of the target value in reliable manner. A particular embodiment of the method according to the invention has been found effective in practice wherein the first and second region both extend over nine source values in the grid.

The adjustment of the interpolated value to the local maximum or minimum within the scope of the present invention can be performed per se in diverse ways. A further particular embodiment of the method according to the invention is however characterized in that the final target value is a weighted average of the target value determined on the basis of interpolation and the local maximum and minimum, wherein a weighting factor is employed which depends on average local dynamics of the source values located around the target value and the

relative location of the target value determined on the basis of interpolation relativeto the local maximum and minimum.

In order to determine the local minima, maxima and dynamics it isper se possible to carry out a separate calculation for each target value to be determined. A preferred embodiment of the method according to the invention is however characterized in that for all source values an associated local minimum and maximum and an associated dynamic value is determined beforehand so as to be read for the purpose of determining the target value. A calculation is herein performed once for all source values together in order to determine said values, so that these are then immediately available. This saves considerable calculation time since calculations which would otherwise be performed repeatedly now take up calculation time once-only.

The invention is not only suitable for data with only a single information component but also for data in the form of source values with separate numerical values for separate information components. In accordance with a further embodiment of the method according to the invention, for each information component a target value located among the sourcevalues is herein determined individually for this information component.

The invention will now be further elucidated with reference to an embodiment and an associated drawing. In the drawing:

figure1 shows the enlargement of a first image based on an existing technique making using of pixel expansion;

figure2 shows an enlargement of the first image based on a second existing technique making using solely of pixel interpolation;

figure 3 shows an enlargement of the first image based on an embodiment of the method according to the present invention;

figure 4 shows the enlargement of a second image based on an existing technique making using of pixel expansion;

figure 5 shows an enlargement of the second image based on a second existing technique making using solely of pixel interpolation; and

figure 6 shows an enlargement of the second image based on the embodiment of the method according to the present invention used in figure 3.

Although the invention lends itself in principle to any type of data wherein the exact bit value is not critical, it is best elucidated within the scope of the present invention on the basis of an example with graphic data in the form of an image S. The data on the basis of which the image can be constructed is possibly already in the form of a grid or matrix corresponding with the pixels of the image, with for each pixel a numerical source value indicating a colour value or, with a view to the method according to the invention, is brought into such a form. In the case of a monochromatic image the colour value amounts only to an intensity, for instance a grey value; in the case of a colour image this will be a set of for instance three values, one for each basic colour. A much used format in which images are digitally stored is the so-called bitmap format which, for each pixel of a colour image, comprises three channels of 8 bits each, and therefore has 256 values for each basic colour. This format can be employed relatively directly by the method according to the invention, other formats possibly require a conversion similar to that with which such a format is transferred to the (image) memory of a computer.

Assuming a black/white image S, a part of the thus assembled matrix is shown by the grid of figure 7, wherein the points in the grid represent the pixels of the source image S with for each grid point S_{ij} a discrete value of I_{ij} from 0 to 255 from the matrix to thereby designate the grey value of the relevant pixel. In order to enlarge such an image while retaining resolution, intermediate points have to be created, of which the value of the grey value has to be calculated. One of these points T is shown in the figure.

A first estimate of the grey value I_t of the intermediate pixel T can be obtained by interpolation on the basis of the values of the surrounding pixels. The point of departure herefor in this example is a weighted average of the values of the surrounding pixels, wherein the weighting assigned to each pixel is highly dependent on its distance from T. A more particular point of

departure herein for the weighting factors is a normalized Gaussian distribution, of which pixel T forms the origin. Because of the sharp fall in the weighting factors according to this curve, a finite region A of for instance 4x4 pixels around T suffices for the interpolation, which pixels are hatched in the figure. On the basis of this interpolation an interpolated grey value P_t results for the pixel T to be calculated in accordance with the following relation:

$$P_t = \sum_{(i,j)\in A} G_{ij} I_{ij}, \; where \sum_{(i,j)\in A} G_{ij} = 1$$

According to the invention a local maximum and a local minimum around the pixel T to be calculated is also determined in addition to the interpolated value P_t. In the embodiment described here the starting point for this purpose is a reference region B of 4x4 pixels $S_{-1,-1}$, $S_{0,0}...S_{2,2}$, an origin $S_{0,0}$ of which is formed by the pixel in the original image lying just in front of the pixel for calculating. This region is shown hatched in the figure. A local maximum I_{max} and a local minimum I_{min} of the grey values of the original pixels are determined within this region.

In addition, the local dynamics in the grey values are determined according to the invention within a reference region around the pixel T for calculating. The starting point therefor in this embodiment is the same reference region B as that in which the local minimum and maximum have been determined. These dynamics provide a measure for the hardness or contrast of the image and are derived in this embodiment from the normalized average difference between the grey values of the pixels S_{ij} in reference region B and a weighted average of the pixels in a reference region C of 5x5 pixels around the pixel S_{ij} for which the local dynamics has to be calculated. This region C therefore differs for each pixel S_{ij} and is indicated by way of example in the figure for S_{00}. This is expressed in the following formula:

$$D_{ij} = \sum_{(ij)\in B} G_{ij} \cdot \left\| I_{ij} - I_{gem(i,j)} \right\|$$

$$where \;\; I_{gem(ij)} = \sum_{(p,q)\in C_{ij}} I_{pq} \cdot G_{pq}' \;\; with \sum_{(i,j)\in B} G_{ij} = 1 \;\; and \sum_{(p,q)\in C_{ij}} G_{pq} = 1$$

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The starting point for the weighted average I_{gem} here are weighting factors G'_{pq} on the basis of a normalized Gaussian distribution which attributes a greater weighting to pixels close to the pixel T for calculating than to further removed pixels. For the resulting factor D_{ij} there applies: $0 \leq D_{ij} \leq 1$. A value $D_{ij}=1$ indicates that the source image in the relevant region is very hard, i.e. has very sharp transitions in intensity, while a value $D_{ij}=0$ indicates precisely the opposite, i.e. no differences in intensity occur within the region. The local dynamics D_t associated with the pixel T to be calculated are derived from the weighted average of the values D_{ij} from the reference region B around the pixel T to be calculated.

The grey value of the pixel T to be calculated is established by adjusting the interpolated value P_t to the local maximum or minimum on the basis of the thus found hardness value D_t. Taken for this purpose in this embodiment is a weighted average of P_t and the local maximum and minimum, wherein a weighting factor is applied which depends on the difference from P_t and is proportional to the hardness value D_t. This is expressed for instance by the following formula applied in this example:

$$I_t = P_t.(1-D_t) + D_t.\left[I_{min} + (I_{max} - I_{min}).\sin_n\left(\frac{P_t - I_{min}}{I_{max} - I_{min}}\right)\right]$$

where $\sin_0(t) = \tfrac{1}{2} + \tfrac{1}{2}.\sin(\pi(t - \tfrac{1}{2}))$ *and* $\sin_n(t) = \sin_0.\sin_{n-1}(t)$ *with* $n \approx 5$

If in the relevant reference region B the source image is completely level and has no differences in intensity, which is reflected by a value D=0, no shifting or adjustment of the interpolated value P_t, takes place. In the case of a comparatively hard image with great differences in intensity, wherein D will move in the direction of a value D= 1, the adjustment will in contrast be maximal. The final value I_t will in that case be shifted to the local minimum or maximum, depending on which value lies closest to the interpolated value P_t, thereby resulting in more definition. The local dynamics of the original image S are thus taken into account in the final grey value I_t, which is calculated for the pixel T to be added.

The foregoing algorithm is applied for all pixels which have to be calculated among or adjacently of the original pixels in order to create the desired enlargement while retaining resolution. In practice this means that for all pixels of the original source image the associated local maxima, minima and average hardness values are calculated beforehand so that these are then immediately available for the above stated calculations. The stated algorithm allows of simple translation into computer software with which a suitable computer can be loaded to perform the calculations fully automatically. In a user interface adapted thereto setting options can be offered for fine-tuning of the size of the reference regions, the relations for the weighting factors and other parameters.

The result on the basis of this embodiment of the method according to the invention is shown in figures 3 and 6 for respectively a relatively hard source image in the form of a sharply defined character and a more variegated source image corresponding with a photographic image. It can clearly be seen that the definition of the character in figure 3 has been retained despite the great enlargement thereof, while the variegation in the image of figure 6 is retained with the method according to the invention and is even better preserved than on the basis of solely an interpolation method as shown in figure 5.

Although the invention has been further elucidated above with reference to only two embodiments, it will be apparent that the invention is by no means limited to the given embodiments. The invention can thus also be applied to images with more colours, wherein the above stated algorithm is applied separately to each basic colour. The invention can advantageously also be applied for the interpolation of sound data and other data with noncritical bit values while retaining dynamics. The above stated weighting factors and frames of reference, although very effective, have been given solely as examples. Depending on the concrete situation, a fine-tuning thereof can take place to further enhance the quality of the final result. Larger, smaller or identical reference regions can for instance thus be applied to calculate the various above stated factors and, in order to determine the final grey value of the pixel for calculating, a different algorithm can also be chosen which takes account of the local dynamics derived in this pixel and the local maximum and minimum.

The invention generally provides a method of interpolating data while retaining dynamics, which implies that the character and the definition of the source data is retained to a significant degree in the result.

Claims

1. Method for processing data in the form of a grid of discrete source values, wherein at least one target value (T) within a region (A) of source values is determined by means of interpolation in said region (A) of source values characterised in that a minimum value (I_{min}) and a maximum value (I_{max}) are determined within a local region of source values around the target value (T), in that a measure of the dynamics is determined within a local region (B) of source values around the target value (T) and in that the target value is calculated by weighted interpolation is adjusted in the direction of either said minimum value or said maximum value on the basis of said determined measure of the dynamics.

2. Method according to claim 1 characterised in that said measure of dynamics is determined as a normalized weighted value of the absolute differences ($||I_{ij} - I_{gem}||$) in source values within said local region (B).

3. Method according to claim 2 characterized in that one of said absolute differences ($||I_{ij} - I_{gem(ij)}||$) is calculated for each one of the source values in said local region (B), and in that each said difference ($||I_{ij} - I_{gem(ij)}||$) is calculated between a given one (I_{ij}, $ij \in B$) of said source values and a weighted average ($I_{gem(ij)}$) of source values in a further local region (C) corresponding to said given one source value.

4. Method according to any of the preceding claims characterized in that the direction in which said adjustement is performed depends on the relative difference between said target value calculated by weighted interpolation (P_0) and said minimum and maximum value (I_{min},I_{max}).

5. Method according to any of the preceding claims characterized in that use is made of weighted interpolation on the basis of a non-linear density distribution which assigns a heavier weighting to source values located closer in the grid than to source values located further away, in particular a Gaussian distribution, at least an exponential density distribution.

AMENDED SHEET

6. Method according to any of the preceding claims characterized in that a source value which lies in the grid closest to the target value to be determined, is taken as source of a region extending over a finite number of mutually adjacent source values and that the local maximum and the local minimum are determined in this region.

7. Method as claimed in claim 6, characterized in that the measure for the dynamics the source values is determined in a second region extending over a finite number of mutually adjacent source values, which second region is optionally of the same size as the first region in which the local maximum and minimum are determined.

8. Method as claimed in claim 7, characterized in that the dynamics are derived from a normalized difference between a source value and an average of all source values in the second region.

9. Method as claimed in claim 8, characterized in that for the average of all source values in the second region a weighted average is taken which assigns a heavier weighting to source values located closer in the grid than to source values located further away and which particularly utilizes a non-linear density distribution for the purpose of determining the weighting factors and more particularly from a Gaussian distribution, at least from an exponential density distribution.

10. Method according to any of the preceding claims characterized in that the final target value is a weighted average of the target value determined on the basis of interpolation and the local maximum and minimum, wherein a weighting factor is employed which depends on average local dynamics of the source values located around the target value to be determined and the relative location of the target value determined on the basis of interpolation relative to the local maximum and minimum.

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ABSTRACT OF THE DISCLOSURE

In a method for processing data in the form of a grid of discrete source values, at least one target value situated among the source values is determined by interpolation. Account is also taken of the character and the definition of the source data by determining a local minimum and a local maximum of the surrounding source values in a region round the target value for determining and by determining a measure for the dynamics of the surrounding source values in a region round the target value to be determined. The target value calculated by interpolation is adjusted in the direction of either the local maximum or the local minimum on the basis of the thus calculated measure for the dynamics of the surrounding source values in order to express the character and the definition of the source data.

Method for data processing

The present invention relates to a method for processing data in the form of a grid of discrete source values, wherein at least one target value within a region of source values is determined by means of interpolation in said region of source values.

Such a method can be used for data of diverse nature, and particularly to expand, compress or decompress computer data with a non-critical bit value, such as for instance sound and animation files. The starting point is always a one- or multi-dimensional grid of discrete source values among which concrete target values have to be predicted by means of interpolation. The source values herein comprise numerical values which, in the case of for instance an image, indicate the colour intensity of a basic colour present therein and, in the case of a sound file, represents the frequency, i.e. the pitch, or the intensity thereof. In the case of other types of data a different information component in the source data will similarly be taken as measure.

For digital images there exists a number of more or less standardized forms in which the data is stored. The so-called bitmap format is for instance a form wherein the data is stored in a series of discrete numerical values. This series can be converted comparatively simply into a two-dimensional matrix of source values which each indicate the colour intensity of pixels corresponding therewith. In a monochromatic image there thus results a single matrix, while in a colour image such a matrix can be constructed for each of the basic colours.

One of the simplest ways of enlarging such an image is to expand the discrete pixels. The result hereof is shown in figures 1 and 4, wherein the lower image T l is roughly a five-fold enlargement of the source image S. It can be seen clearly that such a method of enlargement detracts significantly from the resolution of the final image. Because each pixel of the source image S reappears in the result T1 as a rectangular image area of a uniform colour (intensity), a clear block structure is created which does not correspond with the original source image.

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A better result is obtained by determining target values among the source values in the output data by interpolation. In the case of an image the most probable colour value of an intermediate target value is herein determined on the basis of the colour values of a group of surrounding pixels. The starting point here is preferably a weighted average of the colour values of the surrounding pixels, wherein a heavier weighting is normally assigned to pixels located closer than to pixels located further away. The result of such a method, which is applied by many modern graphic computer programs in a form which may differ somewhat from each other, is shown in figures 2 and 5. The point of departure is the same source image S and the same enlargement factor as in the other figures to obtain the end result T2. A block structure as in a simple pixel expansion is thus avoided to a significant extent in that pixels of the source material S are as it were smeared in the end result T2. While for an image such as that in figure 5 this does produce a reasonable result, the image of figure 2 still loses a lot of its definition because the edges of the image become relatively blurred. Such blurred edges are relatively unavoidable assuming an interpolation technique since interpolation between black and white as in the present image will always produce a certain grey value at the edges. The larger the enlargement chosen, the more pronounced this effect becomes.

The present invention has for its object to provide a method of the type stated in the preamble which to at least a significant extent prevents such a blurring of the image, so that the quality of the image is better preserved.

In order to achieve the stated objective a method of the type stated in the preamble has the feature according to the invention that in a region round the target value for determining a local minimum and a local maximum is determined of the surrounding source values, that in a region round the target value to be determined a measure for the dynamics of the surrounding source values is determined and that the target value calculated by interpolation is adjusted in the direction of either the local maximum or the local minimum on the basis of the calculated measure for the dynamics of the surrounding source values. Not only is an intermediate value herein determined by interpolation, an analysis is also carried out in the source data in order to define the dynamics or contrast thereof in at least the region where a

new target value has to be calculated. On the basis of the thus determined dynamics the interpolated value is adjusted more or less to the value of a local minimum or maximum. In the case of for instance an already relatively blurred source image, the thus adjusted target value will not differ from the interpolated value, or hardly so, but in the case of a relatively dynamic image with sharp local differences in the source values this adjustment will be capable of shifting the interpolated value considerably toward the local maximum or minimum so that the contrast in the source data is retained to a significant degree. The result T3 of an embodiment of the method according to the invention is illustrated in figures 3 and 6, utilizing the same source image S and expansion factor as in the other figures, and clearly shows the improvement compared to the existing expansion techniques.

In a particular embodiment the method according to the invention has the feature that a source value which lies closest to the target value for determining in the grid is taken as source of a region extending over a finite number of mutually adjacent source values and that the local maximum and the local minimum are determined in this region. In order to determine the local minimum and maximum for each target value which has to be calculated a uniform framework is herein always used as starting point with just as large a number of source values as reference. The same applies for the determining of the local dynamics of the source values in a further particular embodiment of the method according to the invention, characterized in that the measure for the dynamics of the source values is determined in a second region extending over a finite number of mutually adjacent source values, which second region is optionally of the same size as the first region in which the local maximum and minimum are determined.

In the context of the present invention local dynamics in the source values are understood to mean the degree in which the source values in the relevant region differ from each other and also the steepness with which these differences are present. A further particular embodiment of the method according to the invention comprises in this respect an algorithm which assigns a numerical value hereto and is characterized for this purpose in that the dynamics are derived from a normalized difference between a source value and an average of all source values in the second region. For the average of all source values in the second region

In the context of the present invention local dynamics in the source values are understood to mean the degree in which the source values in the relevant region differ from each other and also the steepness with which these differences are present. A further particular embodiment of the method according to the invention comprises in this respect an algorithm which assigns a numerical value hereto and is characterized for this purpose in that the dynamics are derived from a normalized difference between a source value and an average of all source values in the second region. For the average of all source values in the second region a weighted average is herein preferably taken which assigns a heavier weighting to source values located closer in the grid than to source values located further away and which particularly utilizes a non-linear density distribution for the purpose of determining the weighting factors and more particularly a Gaussian distribution, at least an exponential density distribution.

In order to determine the different factors which play a part in predicting the target value within the scope of the invention, the starting point is always a number of source values in a finite first and second region as frame of reference. Relatively far-removed source values can be ignored because they make no or hardly any contribution towards the precision with which the target value is calculated and can even detract from this precision in that there is alack of any relationship with the target value for predicting. The calculation time of the method moreover increases when more source values are taken as frame of reference. Conversely, only one or two reference values will in many cases be too few to enable prediction of the target value in reliable manner. A particular embodiment of the method according to the invention has been found effective in practice wherein the first and second region both extend over nine source values in the grid.

The adjustment of the interpolated value to the local maximum or minimum within the scope of the present invention can be performed per se in diverse ways. A further particular embodiment of the method according to the invention is however characterized in that the final target value is a weighted average of the target value determined on the basis of interpolation and the local maximum and minimum, wherein a weighting factor is employed which depends on average local dynamics of the source values located around the target value and the

relative location of the target value determined on the basis of interpolation relativeto the local maximum and minimum.

In order to determine the local minima, maxima and dynamics it isper se possible to carry out a separate calculation for each target value to be determined. A preferred embodiment of the method according to the invention is however characterized in that for all source values an associated local minimum and maximum and an associated dynamic value is determined beforehand so as to be read for the purpose of determining the target value. A calculation is herein performed once for all source values together in order to determine said values, so that these are then immediately available. This saves considerable calculation time since calculations which would otherwise be performed repeatedly now take up calculation time once-only.

The invention is not only suitable for data with only a single information component but also for data in the form of source values with separate numerical values for separate information components. In accordance with a further embodiment of the method according to the invention, for each information component a target value located among the sourcevalues is herein determined individually for this information component.

The invention will now be further elucidated with reference to an embodiment and an associated drawing. In the drawing:

figure1 shows the enlargement of a first image based on an existing technique making using of pixel expansion;

figure2 shows an enlargement of the first image based on a second existing technique making using solely of pixel interpolation;

figure 3 shows an enlargement of the first image based on an embodiment of the method according to the present invention;

figure 4 shows the enlargement of a second image based on an existing technique making using of pixel expansion;

figure 5 shows an enlargement of the second image based on a second existing technique making using solely of pixel interpolation; and

figure 6 shows an enlargement of the second image based on the embodiment of the method according to the present invention used in figure 3.

Although the invention lends itself in principle to any type of data wherein the exact bit value is not critical, it is best elucidated within the scope of the present invention on the basis of an example with graphic data in the form of an image S. The data on the basis of which the image can be constructed is possibly already in the form of a grid or matrix corresponding with the pixels of the image, with for each pixel a numerical source value indicating a colour value or, with a view to the method according to the invention, is brought into such a form. In the case of a monochromatic image the colour value amounts only to an intensity, for instance a grey value; in the case of a colour image this will be a set of for instance three values, one for each basic colour. A much used format in which images are digitally stored is the so-called bitmap format which, for each pixel of a colour image, comprises three channels of 8 bits each, and therefore has 256 values for each basic colour. This format can be employed relatively directly by the method according to the invention, other formats possibly require a conversion similar to that with which such a format is transferred to the (image) memory of a computer.

Assuming a black/white image S, a part of the thus assembled matrix is shown by the grid of figure 7, wherein the points in the grid represent the pixels of the source image S with for each grid point S_{ij} a discrete value of I_{ij} from 0 to 255 from the matrix to thereby designate the grey value of the relevant pixel. In order to enlarge such an image while retaining resolution, intermediate points have to be created, of which the value of the grey value has to be calculated. One of these points T is shown in the figure.

A first estimate of the grey value I_t of the intermediate pixel T can be obtained by interpolation on the basis of the values of the surrounding pixels. The point of departure herefor in this example is a weighted average of the values of the surrounding pixels, wherein the weighting assigned to each pixel is highly dependent on its distance from T. A more particular point of

departure herein for the weighting factors is a normalized Gaussian distribution, of which pixel T forms the origin. Because of the sharp fall in the weighting factors according to this curve, a finite region A of for instance 4x4 pixels around T suffices for the interpolation, which pixels are hatched in the figure. On the basis of this interpolation an interpolated grey value P_t results for the pixel T to be calculated in accordance with the following relation:

$$P_t = \sum_{(i,j)\in A} G_{ij} I_{ij}, \textit{ where } \sum_{(i,j)\in A} G_{ij} = 1$$

According to the invention a local maximum and a local minimum around the pixel T to be calculated is also determined in addition to the interpolated value P_t. In the embodiment described here the starting point for this purpose is a reference region B of 4x4 pixels $S_{-1,-1}, S_{0,0} \ldots S_{2,2}$, an origin $S_{0,0}$ of which is formed by the pixel in the original image lying just in front of the pixel for calculating. This region is shown hatched in the figure. A local maximum I_{max} and a local minimum I_{min} of the grey values of the original pixels are determined within this region.

In addition, the local dynamics in the grey values are determined according to the invention within a reference region around the pixel T for calculating. The starting point therefor in this embodiment is the same reference region B as that in which the local minimum and maximum have been determined. These dynamics provide a measure for the hardness or contrast of the image and are derived in this embodiment from the normalized average difference between the grey values of the pixels S_{ij} in reference region B and a weighted average of the pixels in a reference region C of 5x5 pixels around the pixel S_{ij} for which the local dynamics has to be calculated. This region C therefore differs for each pixel S_{ij} and is indicated by way of example in the figure for S_{00}. This is expressed in the following formula:

$$D_{ij} = \sum_{(ij)\in B} G_{ij} . \left\| I_{ij} - I_{gem(i,j)} \right\|$$

$$\textit{where } I_{gem(ij)} = \sum_{(p,q)\in C_{ij}} I_{pq}.G_{pq}' \textit{ with } \sum_{(i,j)\in B} G_{ij} = 1 \textit{ and } \sum_{(p,q)\in C_{ij}} G_{pq} = 1$$

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The starting point for the weighted average I_{gem} here are weighting factors G'_{pq} on the basis of a normalized Gaussian distribution which attributes a greater weighting to pixels close to the pixel T for calculating than to further removed pixels. For the resulting factor D_{ij} there applies: $0 \leq D_{ij} \leq 1$. A value $D_{ij}= 1$ indicates that the source image in the relevant region is very hard, i.e. has very sharp transitions in intensity, while a value $D_{ij}=0$ indicates precisely the opposite, i.e. no differences in intensity occur within the region. The local dynamics D_t associated with the pixel T to be calculated are derived from the weighted average of the values D_{ij} from the reference region B around the pixel T to be calculated.

The grey value of the pixel T to be calculated is established by adjusting the interpolated value P_t to the local maximum or minimum on the basis of the thus found hardness value D_t. Taken for this purpose in this embodiment is a weighted average of P_t and the local maximum and minimum, wherein a weighting factor is applied which depends on the difference from P_t and is proportional to the hardness value D_t. This is expressed for instance by the following formula applied in this
example:

$$I_t = P_t.(1-D_t) + D_t.\left[I_{min} + (I_{max} - I_{min}).\sin_n\left(\frac{P_t - I_{min}}{I_{max} - I_{min}}\right)\right]$$

$$\textit{where } \sin_0(t) = \tfrac{1}{2} + \tfrac{1}{2}.\sin(\pi(t - \tfrac{1}{2}) \textit{ and } \sin_n(t) = \sin_0.\sin_{n-1}(t) \textit{ with } n \approx 5$$

If in the relevant reference region B the source image is completely level and has no differences in intensity, which is reflected by a value D=0, no shifting or adjustment of the interpolated value P_t, takes place. In the case of a comparatively hard image with great differences in intensity, wherein D will move in the direction of a value D= 1, the adjustment will in contrast be maximal. The final value I_t will in that case be shifted to the local minimum or maximum, depending on which value lies closest to the interpolated value P_t, thereby resulting in more definition. The local dynamics of the original image S are thus taken into account in the final grey value I_t, which is calculated for the pixel T to be added.

The foregoing algorithm is applied for all pixels which have to be calculated among or adjacently of the original pixels in order to create the desired enlargement while retaining resolution. In practice this means that for all pixels of the original source image the associated local maxima, minima and average hardness values are calculated beforehand so that these are then immediately available for the above stated calculations. The stated algorithm allows of simple translation into computer software with which a suitable computer can be loaded to perform the calculations fully automatically. In a user interface adapted thereto setting options can be offered for fine-tuning of the size of the reference regions, the relations for the weighting factors and other parameters.

The result on the basis of this embodiment of the method according to the invention is shown in figures 3 and 6 for respectively a relatively hard source image in the form of a sharply defined character and a more variegated source image corresponding with a photographic image. It can clearly be seen that the definition of the character in figure 3 has been retained despite the great enlargement thereof, while the variegation in the image of figure 6 is retained with the method according to the invention and is even better preserved than on the basis of solely an interpolation method as shown in figure 5.

Although the invention has been further elucidated above with reference to only two embodiments, it will be apparent that the invention is by no means limited to the given embodiments. The invention can thus also be applied to images with more colours, wherein the above stated algorithm is applied separately to each basic colour. The invention can advantageously also be applied for the interpolation of sound data and other data with noncritical bit values while retaining dynamics. The above stated weighting factors and frames of reference, although very effective, have been given solely as examples. Depending on the concrete situation, a fine-tuning thereof can take place to further enhance the quality of the final result. Larger, smaller or identical reference regions can for instance thus be applied to calculate the various above stated factors and, in order to determine the final grey value of the pixel for calculating, a different algorithm can also be chosen which takes account of the local dynamics derived in this pixel and the local maximum and minimum.

The invention generally provides a method of interpolating data while retaining dynamics, which implies that the character and the definition of the source data is retained to a significant degree in the result.

Claims

1. Method for processing data in the form of a grid of discrete source values, wherein at least one target value (T) within a region (A) of source values is determined by means of interpolation in said region (A) of source values characterised in that a minimum value (I_{min}) and a maximum value (I_{max}) are determined within a local region of source values around the target value (T), in that a measure of the dynamics is determined within a local region (B) of source values around the target value (T) and in that the target value is calculated by weighted interpolation is adjusted in the direction of either said minimum value or said maximum value on the basis of said determined measure of the dynamics.

2. Method according to claim 1 characterised in that said measure of dynamics is determined as a normalized weighted value of the absolute differences ($\|I_{ij} - I_{gem}\|$) in source values within said local region (B).

3. Method according to claim 2 characterized in that one of said absolute differences ($\|I_{ij} - I_{gem(ij)}\|$) is calculated for each one of the source values in said local region (B), and in that each said difference ($\|I_{ij} - I_{gem(ij)}\|$) is calculated between a given one (I_{ij}, $ij \in B$) of said source values and a weighted average ($I_{gem(ij)}$) of source values in a further local region (C) corresponding to said given one source value.

4. Method according to any of the preceding claims characterized in that the direction in which said adjustement is performed depends on the relative difference between said target value calculated by weighted interpolation (P_t) and said minimum and maximum value (I_{min}, I_{max}).

5. Method according to any of the preceding claims characterized in that use is made of weighted interpolation on the basis of a non-linear density distribution which assigns a heavier weighting to source values located closer in the grid than to source values located further away, in particular a Gaussian distribution, at least an exponential density distribution.

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6. Method according to any of the preceding claims characterized in that a source value which lies in the grid closest to the target value to be determined, is taken as source of a region extending over a finite number of mutually adjacent source values and that the local maximum and the local minimum are determined in this region.

7. Method as claimed in claim 6, characterized in that the measure for the dynamics of the source values is determined in a second region extending over a finite number of mutually adjacent source values, which second region is optionally of the same size as the first region in which the local maximum and minimum are determined.

8. Method as claimed in claim 7, characterized in that the dynamics are derived from a normalized difference between a source value and an average of all source values in the second region.

9. Method as claimed in claim 8, characterized in that for the average of all source values in the second region a weighted average is taken which assigns a heavier weighting to source values located closer in the grid than to source values located further away and which particularly utilizes a non-linear density distribution for the purpose of determining the weighting factors and more particularly from a Gaussian distribution, at least from an exponential density distribution.

10. Method according to any of the preceding claims characterized in that the final target value is a weighted average of the target value determined on the basis of interpolation and the local maximum and minimum, wherein a weighting factor is employed which depends on average local dynamics of the source values located around the target value to be determined and the relative location of the target value determined on the basis of interpolation relative to the local maximum and minimum.

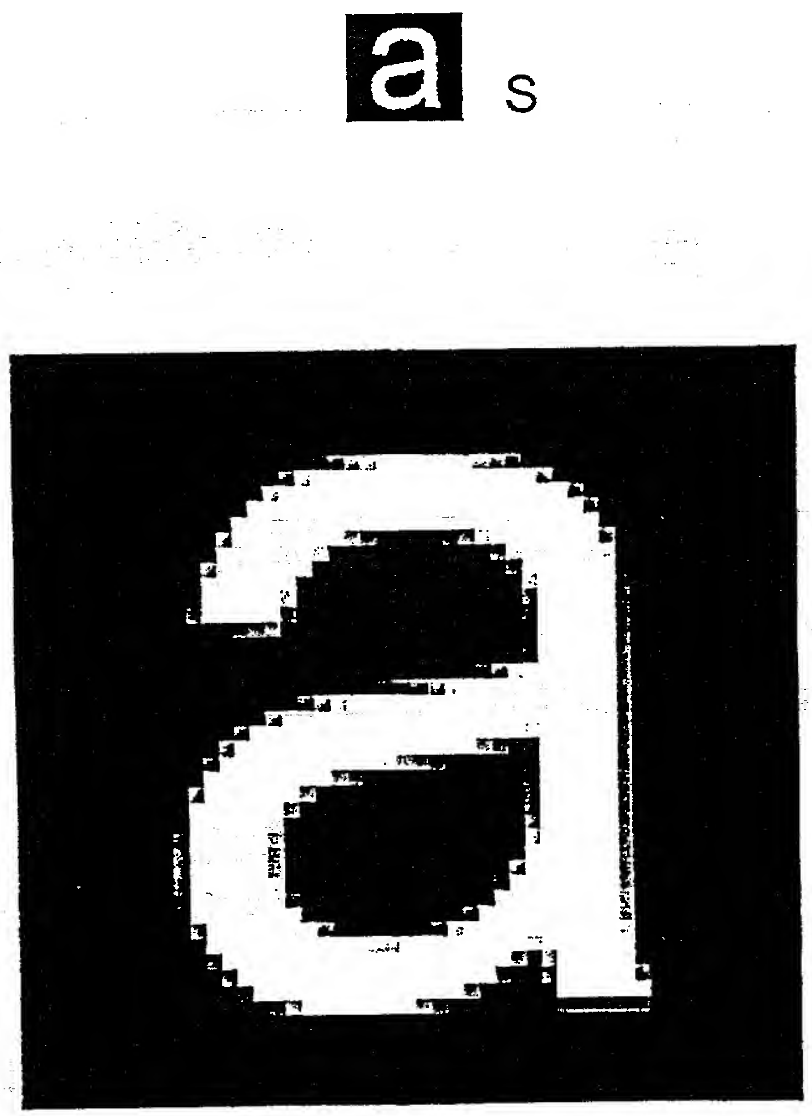


Fig.1

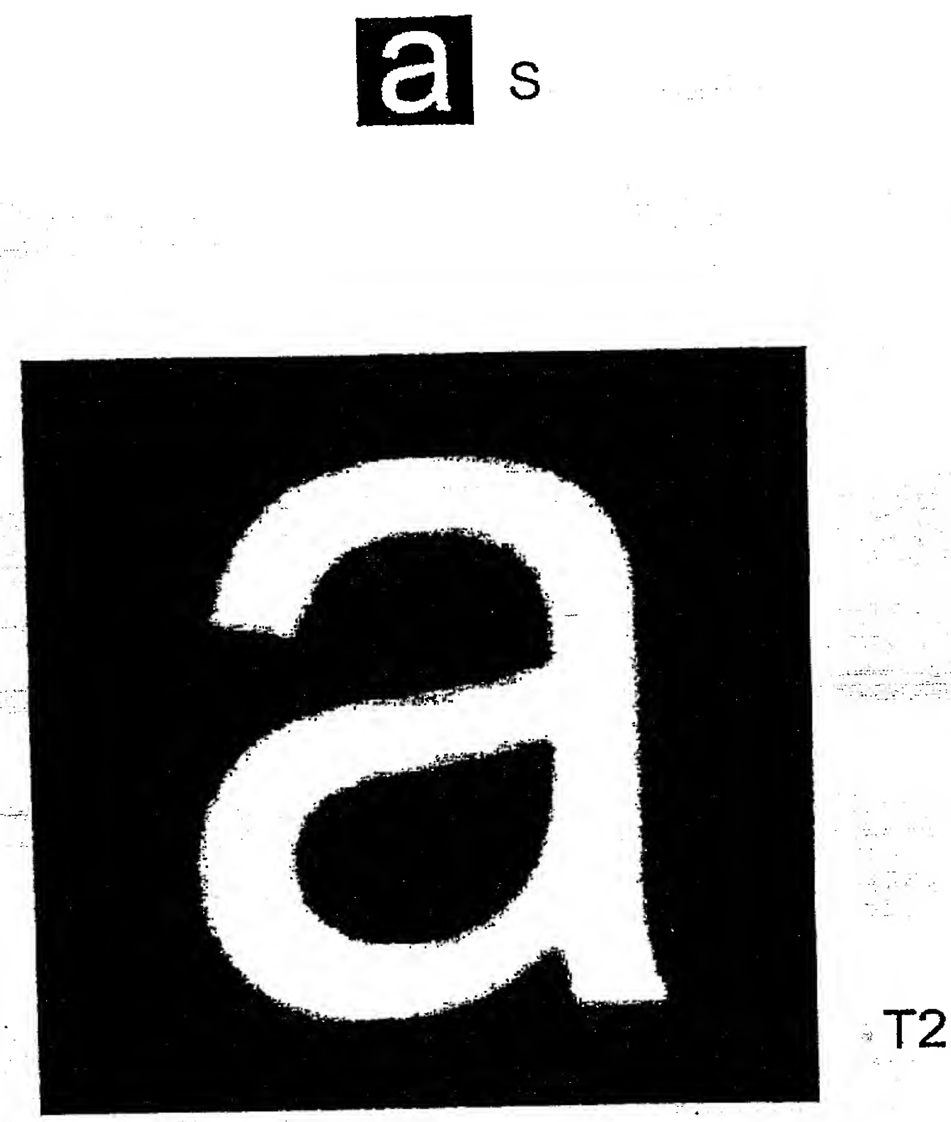
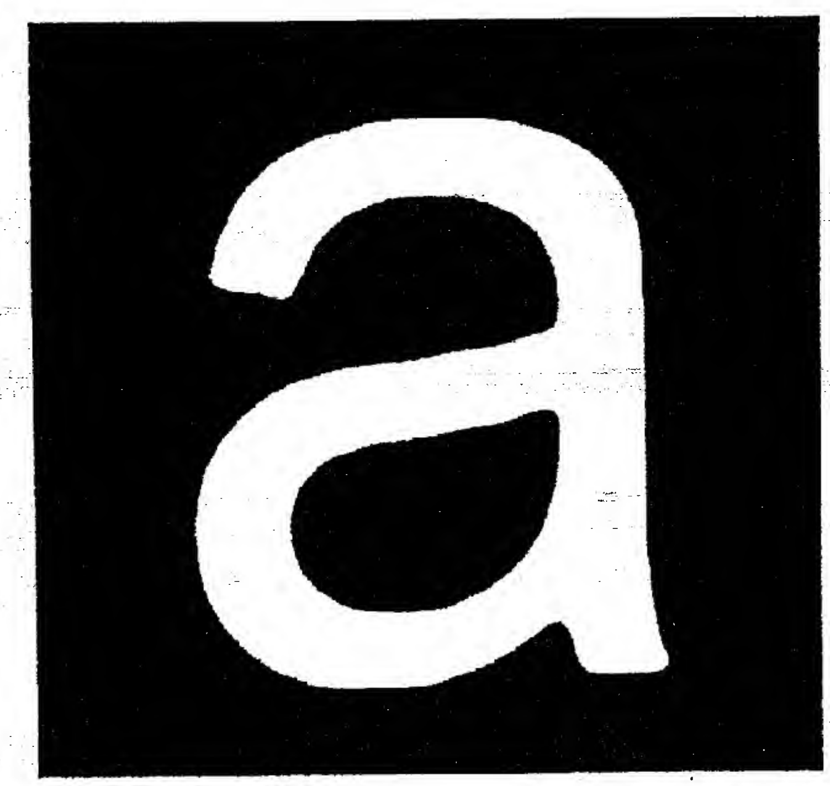


Fig.2

S



T3

Fig.3

S

T1

Fig.4

S

T2

Fig.5

S

T3

Fig.6

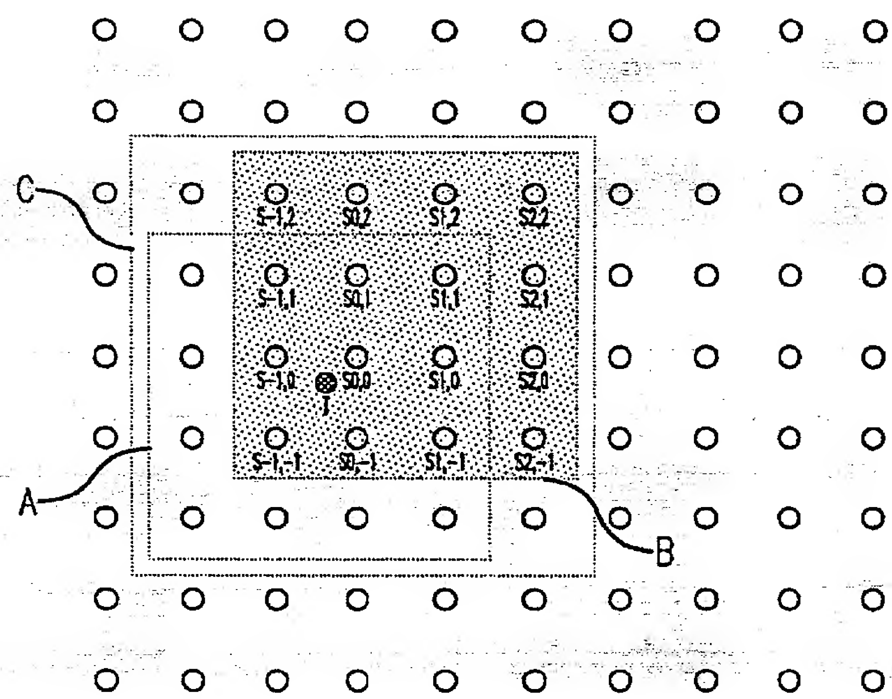

C
A
B
S-1,2
S0,2
S1,2
S2,2
S-1,1
S0,1
S1,1
S2,1
S-1,0
S0,0
S1,0
S2,0
T
S-1,-1
S0,-1
S1,-1
S2,-1

Fig.7

Docket No. 99.1091

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD FOR DATA PROCESSING

the specification of which: *(check one)*

REGULAR OR DESIGN APPLICATION

[ ] is attached hereto.

[X] was filed on 30 November 2001 as application Serial No. 09/980,016 and was amended on ________________ (if applicable).

PCT FILED APPLICATION ENTERING NATIONAL STAGE

[X] was described and claimed in International application No. PCT/NL00/00359 filed on 25 May 2000 and as amended on ________________ (if any).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

PRIORITY CLAIM

I hereby claim foreign priority benefits under 35 USC 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)

Country	Application Number	Date of Filing (day, month, year)	Priority Claimed
The Netherlands	1012198	31 May 1999	Yes

I hereby claim the benefit under Title 35, United States Code §119(e) of any United States provional application(s) listed below:

Provisional Appln. ________________

(Application Serial No.) (Filing Date) (Status--patented, pending, abandoned)

(Complete this part only if this is a continuing application.)

I hereby claim the benefit under 35 USC 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 USC 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

____

(Application Serial No.) (Filing Date) (Status--patented, pending, abandoned)

Docket No. 99.1091

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7

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